Evaluation of Spirulina Algae (*Spirulina platensis*) as a Growth Promoter for Friesian Heifers
1. The Effect on Growth Performance and Nutriets Utilization

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ABSTRACT

This study aimed to evaluate the potential of spirulina algae as a growth promoter for Friesian heifers. The parameters assessed included growth performance, nutrient digestibility, and economic efficiency. Fifteen Friesian heifers, with an average weight of 215.47±9.41 kg, were divided into three groups (n=5).

The control group received a basal diet consisting of 30% concentrate feed mixture (CFM), 30% fresh berseem (*Trifolium alexandrinum*; FB), 20% rice straw (RS), and 20% corn silage (CS) on a dry matter basis. The second and third groups received the same basal diet but were supplemented with 2 g and 4 g of spirulina algae per head per day, respectively. The findings demonstrated significant improvements (P<0.01) in the digestibility coefficients of all nutrients, except for ether extract (EE), as well as in total digestible nutrients (TDN) and digestible crude protein (DCP) for heifers supplemented with either 2 g or 4 g of spirulina/head daily, when compared to the control group. Additionally, total body weight gain and daily weight gain were significantly higher (P<0.01) for the supplemented groups. Intakes of total dry matter (DM), TDN, and DCP were significantly greater (P<0.05) in the spirulina-supplemented groups than in the control group. Furthermore, the feed conversion rate improved (P<0.05) in heifers fed diet supplemented with spirulina. Economic efficiency was higher (P<0.05) in heifers receiving either 2 g or 4 g of spirulina daily compared to the control group.

In conclusion, supplementing the diet of growing Friesian heifers with 4 g of spirulina per head per day significantly improved body weight gain, nutrient digestibility, feed conversion, and economic efficiency. Further research with larger sample sizes and higher spirulina doses is recommended to fully assess its potential as a growth promoter and optimize nutritional utilization in growing Friesian heifers.

Key words: Friesian heifers, spirulina supplementation, digestibility, growth performance and economic efficiency.

INTRODUCTION

Many chemical feed additives have been utilized to enhance animal productivity, but they can have detrimental effects on the animals that consume them. Therefore, it has been important to research natural dietary enhancements. Currently, around 25,000 species of microalgae have been identified, *Spirulina platensis* (also known as *Arthrospira platensis*) emerging as a notable candidate for animal feed applications (Vale *et al.,* 2020). This species is the most widely cultivated photosynthetic prokaryote, largely due to its diverse uses in both food and animal feed. The global production of *Spirulina platensis* is estimated to be around 56,000 tons, with the majority of cultivation taking place in China and the Asia-Pacific region (Cai *et al.,* 2021).

Currently, spirulina is produced on a global scale and is utilized as a dietary supplement for humans and animals (Muhling *et al.,* 2005). Around 50% of the total spirulina production is utilized in feeds for livestock and fish. Microalgae are rich in several compounds, including lipids (1-15%), carotenoids (0.3-4%) and proteins (20-40%). Spirulina, have been explored for their potential as growth stimulants in both feed and food industries (Molino *et al*., 2018).

Spirulina is an edible type of microalgae, characterized by its filamentous structure and circular shape, and it belongs to the group of colored algae (Gupta *et al*., 2008 and Holman & Malau-Aduli, 2012). *Spirulina platensis* has been recognized as an effective natural antioxidant and immune stimulant for human and animal, offering less side effects and being more cost effective compared to synthetic alternatives (Belay, 2002; Khan *et al*., 2005 and Abdel-Daim *et al*., 2013).

Spirulina platensis is rich in high-quality proteins, vitamins, and minerals, and also contains a diverse range of natural plant pigments like carotene and xanthophyll (Farag *et al.,* 2016). Spirulina is a valuable source of essential amino acids, fatty acids,

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as well as vitamins such as B_{12} and various minerals. Additionally, it provides important biological pigments, including carotenoids (Holman & Malau-Aduli, 2012 and Ranjith *et al*., 2013). Additionally, it does not cause any negative effects on the reproductive system, liver or kidneys (Gutierrez-Rebolledo *et al*., 2015 and El-Hashash, 2021).

Spirulina has become increasingly popular in recent years for its use in producing high-quality supplements, both for pharmaceutical products and for animal feed intended for human consumption, due to its rich protein content (Abd El Baky *et al*., 2015; Koyande *et al*., 2019 and Soni *et al*., 2019).

This study aimed to examine the effects of different levels of spirulina supplementation to the ration of Friesian heifers on growth performance, nutritional utilization and economic efficiency.

MATERIALS AND METHODS

The trial work was conducted at the Sakha Research Station affiliated with the Animal Production Research Institute (APRI), Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Egypt. In cooperation with Department of Animal and Poultry Production, Faculty of Technology and Development, Zagazig University, Zagazig, Egypt. The trial work began in March 2023 and ended in August 2023. Due to the institute's policy, calves were not raised for meat production and were used only as fodder. Therefore, male calves were not available and the present trial was carried out on growing Friesian heifers (18 months of age; the weight was low because the concentrate feeds was not sufficient for heifers before period experiment). Chemical analyses were performed at Central laboratory for Soil, Foods and Feedstuffs an International accredited Lab (ISO 17025, since 2012), Faculty of Technology and Development, Zagazig University, Zagazig, Egypt.

In this study, Fifteen Friesian heifers, with an average weight of 215.47±9.41 kg, were divided into three groups (n=5.(The control group received a basal diet consisting of 30% concentrate feed mixture (CFM), 30% fresh berseem (*Trifolium alexandrinum*; FB from the second cut), 20% rice straw (RS), and 20% corn silage (CS) on a dry matter basis. The second and third groups received the same basal diet but were supplemented with 2 g and 4 g of spirulina algae per head per day, respectively. The feedstuffs and basal ration compositions are presented in Table (1). The concentrate feed mixture included 32% undecorticated cotton seed cake, 24% wheat bran, 22% yellow corn, 12% rice bran, 5% linseed cake, 2% molasses, 1% limestone, 1% vitamin and mineral mixture, and 1% common salt. The spirulina (*Spirulina platensis*) used in the study was sourced from 2 M Group Manufacturing Company, located in 10th of Ramadan City, Egypt.

The heifers were housed in semi-open backyard sheds and provided with rations to meet their recommended requirements according to NRC (2001). The concentrate feed mixture was given in two equal portions daily at 8 a.m. and 4 p.m.

Table 1. Chemical composition of feedstuffs and the experimental rations (as DM basis %).

Item	DM%	Composition of DM %					
		OM	CP	CF	EE	NFE	Ash
CFM	90.20	88.22	16.76	9.19	3.76	58.51	11.78
FB	19.61	87.10	12.21	23.50	2.25	49.14	12.90
CS	25.64	89.11	4.72	24.60	2.19	57.60	10.89
RS	91.12	82.21	3.40	31.43	0.86	46.52	17.79
DS	91.54	87.12	52.93	5.29	4.82	24.08	12.88
Chemical composition:							
Organic Matter					87.26		
Dry matter					56.30		
Nitrogen free extract (NFE)					50.72		
Crude fiber (CF)					21.01		
Crude protein					13.12		
Ash					12.74		
Ether extract					2.41		
Ca					0.42		
P					0.24		

CFM = Concentrate feed mixture CS =Corn silage,

FB= Fresh berseem RS= Rice straw,

DS= Dry spirulina algae.

Fresh berseem, corn silage, and rice straw were supplied daily at 10:00 a.m., 12:00, and 15:00 p.m., respectively. Dry spirulina was added to concentrate feed mixture at morning every day. Water was offered to animals free all the time.

Digestibility assessments were performed at the midpoint and endpoint of the trail involving 4 heifers per group to assess the digestibility coefficients and nutritional values. The acid insoluble ash (AIA) method described by Van Keulen and Young (1977) was used in these evaluations. Feces samples were collected from the rectum of each heifer twice daily (12 h intervals throughout the collection period). Samples of feedstuffs were taken at the beginning, middle and end of the collection period (7 days). Representative samples of feedstuffs and feces were chemically analyzed according to the methods of AOAC (2012).

Feed conversion rate was calculated by measuring the amounts of DM, TDN and DCP required to achieve a weight gain of 1 kg.

Economic efficiency is calculated by comparing the cost of feed required to produce one kilogram of gain with the selling price of that kilogram. During the 2023 experimental period, the costs in Egyptian pounds (LE) per ton were as follows: 15,000 LE for the concentrate feed mixture, 650 LE for fresh berseem, 1,350 LE for corn silage, and 550 LE for rice straw. Additionally, the cost of dry spirulina production was 850 LE per kilogram.

Statistical analysis

Data were analyzed statistically using the Least Squares Analysis of Variance method according to Snedecor and Cochran (1982). The analysis was performed with the General Linear Model procedure in SPSS (2013), applying the fixed model specified below:

$Yij = \mu + Si + eij$

Where,

Yij = the observed value of a given dependent variable,

μ = Overall adjusted mean,

Si = Dry spirulina effect (i = 1, 2 and 3),

eij = Random error.

The differences between LSM (least square means) were analyzed by Duncan's New Multiple Range test (Duncan, 1955).

RESULTS AND DISCUSSION

Nutrients digestibility and feeding values:

The digestibility coefficients of nutrients and feeding values for Friesian heifers, influenced by supplementation with green algae (spirulina) are presented in Table (2). With the exception of ether extract (EE), the digestion coefficients of all nutrients, along with the values for total digestible nutrients (TDN) and digestible crude protein (DCP), showed significant improvements ($P<0.01$) in heifers fed rations supplemented with either 2 g spirulina/head daily (2nd group) or 4 g spirulina/head daily (3rd group) than the control group. Positive effects of spirulina supplementation to the rations on digestibility coefficients and nutritional values may be due to the broad spectrum of extremely biologically value compounds that involved in spirulina algae (Carrillo *et al*., 2008; Colla *et al*., 2008 and Kuplys *et al*., 2009). The findings align with studies by Hassanien *et al.* (2015) on dairy goats and Riad *et al*. (2019) on Friesian calves. The improved digestibility in Friesian cows supplemented with spirulina at 1and 2 ml/kg live body weight in drinking water may be a subsequence of the high nutrient density of spirulina and its potential to stimulate the secretion of extracellular enzymes by gut microflora (Gaafar *et al.*, 2017).

Live body weight and body weight gain:

The effects of green algae (spirulina) supplementation on live body weight, total body weight gain, daily weight gain, and relative weight gain in Friesian heifers are presented in Table (3). The initial live body weight of the heifers was nearly identical at the beginning of the experiment in the different experimental groups. Total body weight gain and daily weight gain were improved ($P<0.01$) for heifers fed rations supplemented with either 2 g or 4 g spirulina/head daily, respectively than those fed the control ration. However, the relative weight gain did not show significant changes by addition of green algae (spirulina) to the ration of Friesian heifers. These findings may be due to the improvements in nutrient digestibility and the overall nutritional value, as presented in the Table (2). These findings are consistent with previous research by Riad *et al*. (2019) on Friesian calves; Bezerra *et al.* (2010) and Holman *et al*. (2012) on lambs; Hafez *et al*. (2013) and EL-Sabagh *et al.* (2014) on growing rabbits.

Furthermore, El-Moghazy *et al.* (2023) reported no significant differences in body weight ($P>0.05$) between groups treated with *Spirulina platensis* at doses of 10 and 15 g/head/day compared to those receiving 5 g/head/day. However, significant differences ($P<0.05$) were observed between the treated groups and the control group.

Table 2. Digestibility coefficients and nutritive values of Friesian heifers fed ration supplemented with green algae (spirulina).

Items	1st group (Control)	2nd group (2 g spirulina/head daily)	3rd group (4 g spirulina/head daily)	Sig.
Digestibility coefficients (%)				
DM	65.71^{c}±0.25	67.48^{b}±0.36	69.28^{a}±0.34	**
OM	67.50^{c}±0.21	69.38^{b}±0.42	70.76^{a}±0.40	**
CP	68.36^{b}±0.41	71.39^{a}±0.39	71.54^{a}±0.28	**
CF	66.57^{b}±0.63	71.47^{a}±0.57	72.06^{a}±0.46	**
EE	70.91±0.42	71.52±0.64	74.50±2.92	Ns
NFE	66.56^{b}±054	67.95^{b}±0.40	69.67^{a}±0.51	**
Nutritive values (%)				
TDN	60.56^{c}±032	62.87^{b}±0.37	64.29^{a}±0.43	**
DCP	8.96^{b}±0.05	9.45^{a}±0.05	9.56^{a}±0.04	**

NS= Not significant and **= P< 0.01.

Means having the different letters within the same row, differ significantly (P <0.05).

Table 3. Growth performance of Friesian heifers fed ration supplemented with green algae (spirulina).

Items	1st group (Control)	2nd group (2 g spirulina/head daily)	3rd group (4 g spirulina/head daily)	Sig.
Initial body weight (kg)	218.00±23.14	210.00 ±15.55	218.00 ±11.90	N.S
Final body weight (kg)	320. 00±24.08	328.00 ± 13.38	346.00 ±14.27	N.S
Total weight gain (kg)	102.00^{b} ±2.87	118.00^{a} ± 2.98	128.00^{a} ± 4.06	**
Daily weight gain (kg)	0.73^{b} ± 0 .02	0.84^{a} ± 0 .02	0.91^{a} ± 0 .03	**
Relative weight gain	38.91 ± 3.53	44.50 ± 3.04	45.62 ± 1.69	N.S

NS= Not significant and **= P< 0.01.

Means having the different letters within the same row, differ significantly (P <0.05).

Significant improvements in the growth performance of suckling calves supplemented by *Spirulina platensis* may be due to the pronounced stimulating effect of *Spirulina platensis* on the metabolism during the period of intensive growth of animal organs (Glebova *et al.*, 2018 and El-Moghazy *et al.*, 2023).

Feed intake:

The feed intake of Friesian heifers, when supplemented with green algae (spirulina), is presented in Table (4). The intake of total dry matter (DM), total digestible nutrients (TDN), and digestible crude protein (DCP) were significantly higher (P < 0.05) for heifers that received daily spirulina supplements of either 2 g or 4 g per head, compared to the control group. These findings align with results from Hafez *et al*. (2013) on growing lambs and Riad *et al*. (2019) on Friesian calves. The previous researchers observed that spirulina supplementation slightly improved (P<0.05) feed intake compared with the control. Gaafar *et al.* (2017) showed that spirulina improved significantly (P<0.05) of daily feed intake of Friesian cows supplemented with spirulina and at the levels of 1 ml or 2 ml / kg live body weight in drinking water as compared with the un-supplemented cows (control group).

According to Lamminen *et al.* (2017) and Manzocchi *et al.* (2020), the total dry matter intake of dairy cows was not influenced by supplementary protein or by replacing the rapeseed supplement with a mixture of spirulina and chlorella, or spirulina alone.

Feed conversion ratio:

The feed conversion ratio of Friesian heifers, as influenced by supplementation with green algae (spirulina), is presented in Table (5). The results indicated that feed conversion ratio of Friesian heifers improved (P<0.05) with spirulina supplementation. The amounts of DM, TDN and DCP needed per one kg of weight gain were lower (P<0.05) for Friesian heifers fed ration supplemented with either 2 g or 4 g spirulina/head daily as compared with the control group. The feed conversion rate, based on DM, TDN and DCP was nearly the same for both levels of spirulina supplementation, with no significant differences between them. These results agree with those obtained by EL-Sabagh *et al.* (2014) on growing rabbits and Riad *et al*. (2019) on Friesian calves they

found that feeding spirulina improved feed conversion ratio compared with those fed the control ration (P<0.05). Gaafar *et al.* (2017) reported that Friesian cows fed to spirulina had a significant decrease (P<0.05) in the amounts of DM, TDN, CP and DCP. Also, Al-Yahyaey *et al.* (2022) showed that a better feed conversion ratio for Jabbali goats fed diet supplemented with 2 g and 4 g *Spirulina p*latensis /head/day than in the control group.

Economic efficiency:

The economic efficiency of Friesian heifers in relation to green algae (spirulina) supplementation is presented in Table (6). The results indicated that the daily feed cost was higher (P<0.05) for Friesian heifers fed ration supplemented with either 2 g or 4 g spirulina per head as compared with the control group. However, the feed cost/ kg live /head daily was significantly higher (P<0.05) for control heifers compared to those fed ration supplemented with either 2 g or 4 g spirulina/head daily. Furthermore, both the price of total weight gain and economic efficiency were significantly higher (P<0.05 or P<0.01) for Friesian heifers fed ration supplemented with either 2 g or 4 g spirulina/head daily than those of control one.

Table 4. Average daily feed intake of Friesian heifers fed ration supplemented with green algae (spirulina).

Items	1st group (Control)	2nd group (2 g spirulina/head daily)	3rd group (4 g spirulina/head daily)	Sig.
As fed (kg/day):				
Concentrate feed mixture)	2.92±0.04	2.91±0.01	3.00±0.04	NS
Fresh berseem	13.30±0.07	13.40±0.09	13.50±0.03	NS
Corn silage	6.41^{b}±0.09	6.50^{b} ±0.02	6.70^{a} ±0.03	*
Rice straw	2.00±0.004	2.00±0.04	2.00±0.04	NS
Total DM intake	8.72^{c}±0.01	8.75^{b}±0.01	8.91^{a}±0.004	**
TDN intake	5.28^{c}±0.012	5.50^{b}±0.02	5.73^{a}±0.004	**
DCP intake	0.78^{c}±0.001	0.83^{b}±0.0004	0.85^{a}±0.0004	**

NS= Not significant, * = P< 0.05 and **= P< 0.01.

Means having the different letters within the same row, differ significantly (P <0.05).

Table 5. Feed conversion of Friesian heifers fed ration supplemented with green algae (spirulina).

Items	1st group (Control)	2ndgroup (2g spirulina/head daily)	3rdgroup (4g spirulina/head daily)	Sig.
Feed conversion:				
Kg DM/ kg gain	12.01^{a}± 0.32	10.38^{b}±0 .26	9.75^{b}±0 .32	*
Kg TDN/ kg gain	7.27^{a}±0 .20	6.52^{b}±0 .25	6.27^{b}± 0.21	*
Kg DCP/kg gain	1.08^{a}± 0.03	0.98^{b}±0.02	0.93^{b}±0 .03	*

*= P< 0.05.

Means having the different letters within the same row, differ significantly (P <0.05).

Table 6. Feed efficiency and economic efficiency of Friesian heifers fed ration supplemented with green algae (spirulina).

Items	1st group (Control)	2ndgroup (2 g spirulina/head daily)	3rd group (4 g spirulina/head daily)	Sig.
Feed efficiency:				
kg gain/ Kg DM	0.08^{b}±0 .002	0.10^{a}±0 .002	0.10^{a}±0.004	*
kg gain / Kg TDN	0.14± 0.03	0.15± 0.004	0.16± 0.005	NS
kg gain / Kg DCP	0.93^{b}± 0.03	1.02^{a}±0.03	1.07^{a}±0.03	*
Economic efficiency:				
Daily feed cost (LE)	62.03^{c}±0 .02	64.09^{b}± .14	67.99^{a}± 0.10	**
Price of daily gain (LE)	87.10^{b} ±2.46	101.16^{a}±2.56	109.70^{a}±3.48	**
Economic efficiency%	140.43^{b}±3.99	157.87^{a}±4.27	161.37^{a}±5.26	*

NS= Not significant and **= P< 0.01.

Means having the different letters within the same row, differ significantly (P <0.05).

These findings align with those of Hafez *et al*. (2013) on growing lambs and Riad *et al*. (2019) on Friesian calves who showed that spirulina additive resulted in significant (P<0.05) improvements in economic efficiency. Additionally, Gaafar *et al.* (2017) demonstrated that economic efficiency of Friesian cows supplemented with spirulina was improved significantly (P<0.05). The daily feed cost, total milk yield revenue, daily net revenue and improvement in net revenue all increased significantly (P<0.05) with spirulina supplementation. However, the feed cost per 1 kg of 4% FCM decreased significantly (P<0.05) compared to the control group. Friesian cows supplemented with 2 ml of spirulina / kg live body weight in drinking water was significantly (P<0.05) and recorded the highest average daily feed cost, total revenue of milk yield, net revenue and net revenue improvement, while the control group had the opposite trend with all mentioned items.

In conclusion, spirulina appears to be a valuable feed supplement for enhancing future animal production. Supplementing growing Friesian heifers with 4 g of spirulina per head per day led to improvements in weight gain, nutrient digestibility, feed conversion, and feed cost efficiency. Additional research involving a larger sample of animals and higher spirulina doses is recommended to confirm its potential as a growth enhancer and to optimize nutritional efficiency for growing Friesian heifers.

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الملخص العربي

تقييم طحلب الاسبيرولينا (سبيرولينا بلاتينسيس) كمحفز للنمو في العجلات الفريزيان

١. التأثير علي أداء النمو والتمثيل الغذائي

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هدفت هذه الدراسة لتقييم استخدام طحلب الاسبيرولينا كمحفز للنمو في العجلات الفريزيان. شملت المعايير التي تم قياسها معدلات النمو، هضم العناصر الغذائية والكفاءة الاقتصادية كمؤشرات للدراسة. تم تقسيم خمسة عشر عجلة فريزيان بمتوسط وزن الجسم الحي ٢١٥,٤٧ + ٩,٤١ كجم إلى ثلاث مجموعات تجريبية (٥ عجلات/مجموعة). تم تغذية عجلات المجموعة الأولى(مجموعة المقارنة) على العليقة الأساسية على أساس المادة الجافة والتي تتكون من ٣٠٪ خليط من العلف المركز، ٣٠٪ برسيم طازج، ٢٠٪ قش أرز و٢٠٪ سيلاج ذرة. غذيت المجموعة الثانية والثالثة علي العليقة الأساسية مضاف إليها ٢ جم أو ٤ جم سبيرولينا / رأس يوميا، على التوالي.

أظهرت النتائج تحسن (علي مستوي احتمال ١%) في معاملات الهضم لجميع العناصر الغذائية باستثناء الدهون، وكذلك قيم المركبات الكلية المهضومة والبروتين الخام المهضوم للعجلات التي تغذت على عليقة أساسية مضاف إليها ٢ جم سبيرولينا / رأس يوميا أو ٤ جم سبيرولينا / رأس يوميا مقارنةً بمجموعة المقارنة. بالإضافة إلى ذلك، تحسنت الزيادة الوزنية الكلية للجسم والوزن اليومي (علي مستوي احتمال١%) للمجموعات التي غذيت على عليقة أساسية مضاف إليها سبيرولينا. ذادت القيم الغذائية لكل من المادة الجافة والمركبات الكلية المهضومة والبروتين الخام المهضوم زيادة معنوية (علي مستوي احتمال ٥%) للمجموعات التي غذيت علي عليقة أساسية مضاف إليها سبيرولينا مقارنة بمجموعة المقارنة. علاوة على ذلك،تحسنت نسبة التحويل الغذائي (علي مستوي احتمال ٥%) في العجلات التي تناولت الاسبيرولينا. كانت الكفاءة الاقتصادية أعلى (علي مستوي احتمال ٥%) في العجلات التي أضيف لها ٢ جرام أو ٤ جرام من سبيرولينا يوميًا مقارنة بمجموعة المقارنة.

ونستنتج من الدراسة أن إضافة ٤ جم سبيرولينا/ رأس يوميا لعجلات الفريزيان النامية أدي إلى تحسين وزن الجسم والزيادة الوزنية معاملات الهضم ونسبة التحويل الغذائي والكفاءة الاقتصادية للأعلاف. يجب إجراء المزيد من الدراسات باستخدام عدد أكبر من العجلات وجرعات أعلى من طحلب اسبيرولينا لضمان فاعلية استخدامه كمحفز للنمو والاستخدام الأمثل للأعلاف.

الكلمات المفتاحية: أبقار الفريزيان، مكملات الاسبيرولينا، الهضم، أداء النمو والكفاءة الاقتصادية.